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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Filters and Purifiers for Oil Circulating Systems

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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FILTERS AND PURIFIERS FOR OIL CIRCULATING SYSTEMS

THE operating and maintenance conditions which prevail in a given system will dictate to a large extent the kind of performance that can be obtained with the oil, the equipment's life blood. Good lubricating oils resist unfavorable conditions longer than lower quality oils; no oil, however, can resist these conditions indefinitely and certainly, no oil can ever cure faulty operating conditions, nor substitute completely for inadequate maintenance.

OIL CONDITIONING IS GOOD INSURANCE

A lubricating or hydraulic oil can become contaminated during use even under the most closely controlled operating conditions, and especially rapid contamination can be expected during periods of malfunctioning. Conditioning equipment is necessary to remove these contaminants as soon as possible to insure long oil and equipment life. Of course, oil from contaminated systems can be drained frequently and replaced, but serious damage can result between changes. Adequate provision for oil and equipment protection through use of filters or purifiers, or combinations of these can give significantly extended equipment life with fewer oil changes. It is fully realized that a very definite relationship exists between effective lubrication and oil cleanliness.

Experience has shown that a great majority of the complaints originally assumed to be associated with malfunctioning of the lubricant can in actuality be traced to excessive product contamination in service and inadequate maintenance practices.

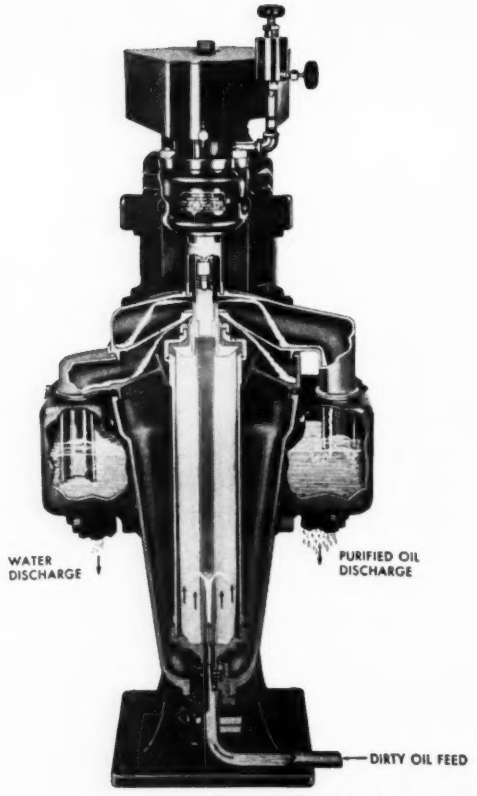
The contaminants encountered with oils in service and the detrimental effects associated with them are discussed.

Contamination from Extraneous Matter

1. *Dirt* and *dust* common to the region in which the equipment operates can gain entrance through breather lines, leakage, or when carried by moisture. It is important to realize the effect of such contaminants on equipment wear, as catalysts in promoting oil oxidation and as emulsion stabilizers with water, promoting sludging conditions. Plugging of oil lines may result and the contaminant effect on water separating characteristics and foaming must also be considered.

2. *Water* from condensation, gland or seal leakage, cooling coil leakage, etc., can cause rusting of equipment parts. This contaminant promotes oil oxidation and sludging and plays a part with dirt in forming emulsions with oil. Metals and metal compounds that act as catalysts in promoting oil oxidation (i.e., zinc, copper, iron, lead, etc.) are considerably more active in the presence of moisture.

3. *Core sand* that has remained in metal castings from the time they were formed in the foundry or *metal particles* from the time equipment was in the



Courtesy of The Sharples Corporation

Figure 1 — Cut-away of centrifuge used for the purification of industrial oils.

machine or repair shop can cause results similar to those described in Item 1.

4. *Metal particles* due to disintegration or wearing of parts such as bearings, piston rings, gears, etc., lead to results similar to those described in Item 1.

5. *Carbon* and other products of partial decomposition or oxidation resulting from destruction of oil or incomplete combustion of fuel (internal combustion engines) lead to further oil oxidation and sludge deposition within the oil system. Hard varnish-like deposits and coking may result at some points in the system.

6. *Fuel dilution* (internal combustion engines) through faulty fuel systems or cold operation has an adverse effect on oil stability and can cause dangerous reduction in oil viscosity.

7. *Anti-Freeze* and cooling system chemicals from water leakage from cooling systems (internal combustion engines) can cause almost immediate oil sludging and some chemical changes may lead to engine seizure.

8. *Miscellaneous contaminants* such as paint from inside surface coatings, asbestos, and packing material, etc., can plug oil lines and cause oil sludging.

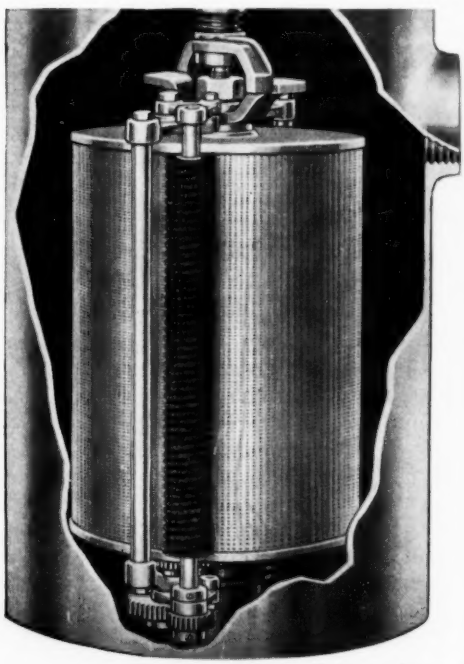
Contaminants Resulting from Oil Oxidation

1. Oil will deteriorate due to oxidation in the presence of air or other oxygen containing media, accompanied by high temperature service. This process is catalyzed by metals and associated compounds especially in fine particle form. Some of the most usual active catalyzers are zinc, lead, iron, and copper. Products of oxidation in the initial stages may be oil soluble but will become oil insoluble as deterioration continues.

2. Some oils deteriorate due to polymerization (linkage of unsaturated oil molecules to form progressively heavier molecules causing oil thickening), as a result of high as well as normal temperature service. Products of polymerization will be oil soluble at the start but they become oil insoluble as the process continues.

3. Some oils develop sludge under lower than normal temperatures of operation where products of contamination combine with the oil to form a mayonnaise-like sludge emulsion. (e.g. in internal combustion engines)

Once the process of oil oxidation starts, the situation becomes progressively worse since it is self-accelerating. The proper selection of oil and the proper selection of auxiliary equipment to maintain it in clean condition is necessary to obtain long



Courtesy of Bowser, Incorporated

Figure 2 — Automatic mechanical cylinder pressure filter of the self-cleaning type. For use where filtering cycles are long and where lubricants contain large quantities of foreign suspended matter.

equipment life with minimum loss of down time, low repair costs and to reduce the frequency of oil changes and general overhauling.

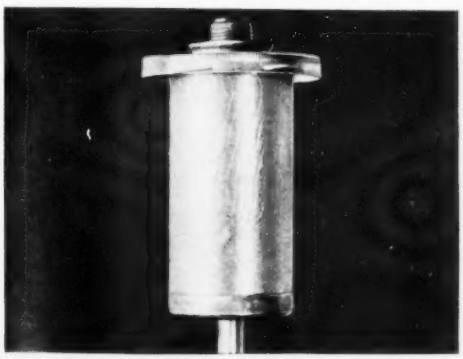
Keeping lubricating oil clean was a logical development along with flood lubrication and both accompanied the perfection of the steam turbine, the internal combustion engine and the hydraulic system. Close cooperation between the oil supplier, equipment manufacturer and the suppliers of oil filters and purifiers assures the consumer the most trouble-free operation and lowest overall operation costs.

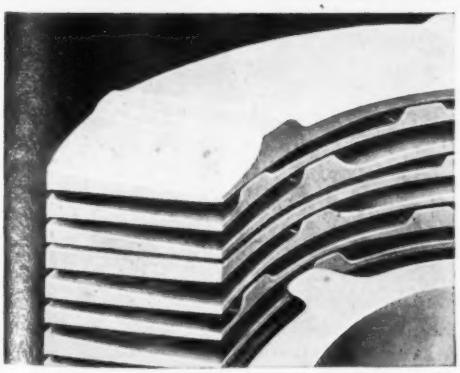
FILTER AND PURIFICATION EQUIPMENT SELECTION

The ultimate in oil conditioning equipment for maintaining oil cleanliness would be the incorporation of a design to permit most efficient purification at the fastest rate involving the least cost and space. Many factors must be considered in the selection of such auxiliary equipment for a given unit.

a. Type and size of unit involved.

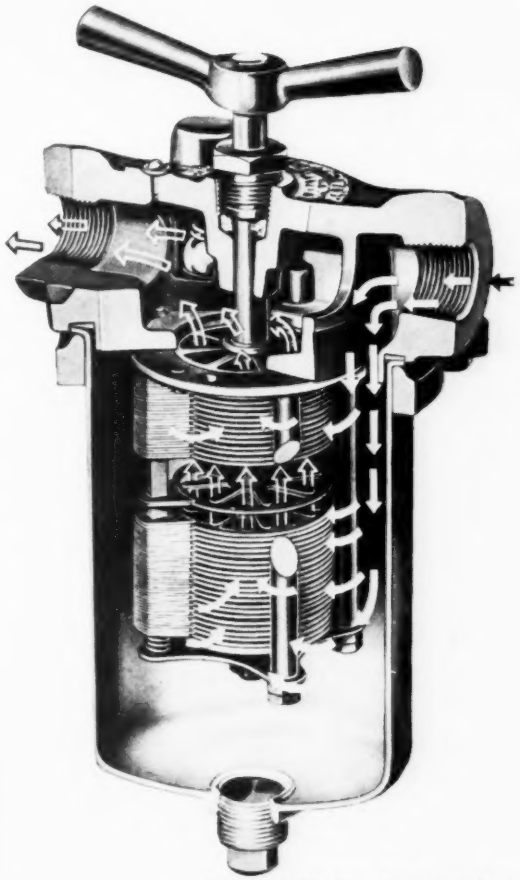
b. Type of oil in use, viscosity, etc.





Courtesy of Purolator Products Inc.

Figure 3 — Cleanable, high flow rate elements for filtration down to .0015" spacing. Constructed of continuous metal ribbon wound edgewise on perforated frame. Projections formed on ribbon provide spacing for oil flow and determine size of particles to be retained.



Courtesy of The Cuno Engineering Corp.

Figure 4 — Cut-away of typical edge-type filter with stationary cleaner blades. Manual or motor drive turning of cartridge through one complete revolution combs out the filtering slots.

c. Economics. (Capital investment, installation and maintenance costs as compared to extended oil and equipment life.)

d. Service involved and conditions of operation.

e. Volume of oil involved.

f. Available space.

g. Type and amount of contamination and combinations of contaminants normally encountered.

h. Adaptability of unit to auxiliary equipment.

i. Type and quality of fuel used (internal combustion engines only).

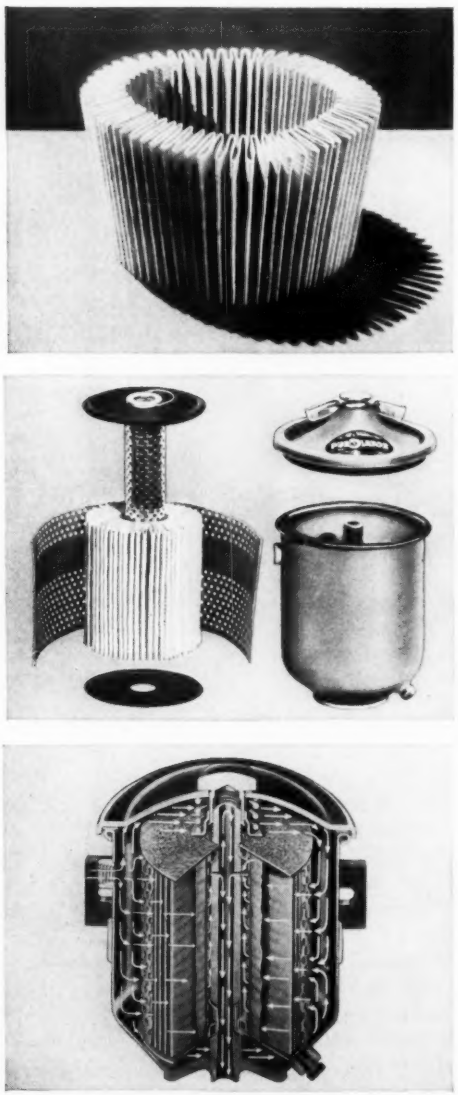
No single method or system of purification is best suited for all operating conditions and equipment. What is entirely suitable for one may be inadequate for another and often a combination of systems is necessary for most efficient purification.

Auxiliary Equipment Available

Oil purifying methods involve either batch oper-

ation, continuous in-service-operation, or a combination of these two. Batch operation may require equipment shutdown while change-over is accomplished and unless two batches of oil are used, shutdown is necessary until the batch has been purified. In addition, *batch operation does not permit contaminant removal as it occurs,* so during the period of build-up serious changes can result.

Oil conditioning is contingent upon two basic types of equipment.



Courtesy of Purolator Products Inc.

Figure 5 — Resin impregnated pleated paper extended area filter are commonly used in internal combustion engine lubricating systems. Applicable to both full-flow, shunt and by-pass systems. Sequence of illustrations indicate the constructional features.

1. A system which can only remove insoluble materials.
   a. Settlers.
   b. Centrifuges.
   c. Filters of the inactive type using either gravity or pressure arrangement.
   d. Metal strainers.
2. A system which not only removes insoluble materials but also the oil soluble oxidation products.
   a. Filters of the active type containing Fuller's earth, charcoal, bone black or some type of activated alumina or clay.
   b. Water-washing to precipitate oil soluble oxidation products followed by use of filter, settler, or centrifuge.

Gravity Settling

1. Settling Tanks.

The simplest and most readily accomplished means of effecting at least partial clarification of a used oil is to allow it to stand quietly for a time in some form of settling tank. During this time, depending on the efficiency of settling and the decanting facilities available, it is generally possible to remove suspended insoluble oxidized material, foreign particles, dirt and water. Gravity separation of such oil contaminants is commonly used in systems with large volumes of oil and systems where water contamination is extensive.

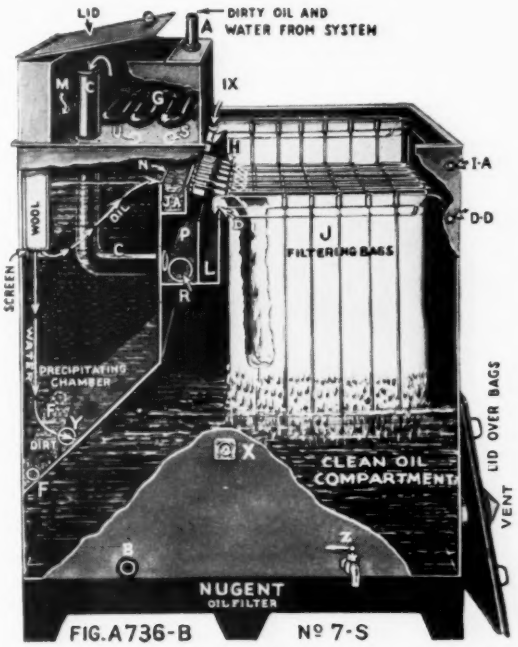
The equipment available for settling will control the effectiveness of the procedure. Some systems are designed to provide rest tanks, so arranged that two batches of oil are available which can be alternated in use. By means of bottom drawoffs, adjustable pump-out lines or manual decanting of the clear oil (in smaller units), the clarified oil is separated from the settled materials. Settling is most effective in flat or horizontal tanks of minimum depth with sloping or trough bottoms.

Settling may be accomplished at any temperature. Some authorities believe that, where time will permit, thorough clarification can be achieved at room temperature. However, it is generally accepted that the best results are obtained at settling temperatures of 120-140°F., except in some steel mill operations where considerable water contamination has resulted in oil emulsification. Under such conditions, settlers may be heated at times to as high as 200°F. Excessively high temperatures or hot spots should be avoided to prevent the possibility of accelerated oxidation. For this reason, heating coil temperatures should be accurately controlled. Saturated steam usually not over 50#/sq. in. or preferably low pressure exhaust steam or hot water should be used so that the skin temperature of the heating element is not excessive. Little settling will occur while he

oil is being heated because of the convection currents created. Settling at low temperatures is generally not satisfactory because the rate of separation is retarded due to the higher viscosity of the oil. Although gravity settling permits separation of some of the soluble oxidation products, primarily this system is used for the separation of water, insoluble sludge, dirt, and other materials sufficiently different in gravity from the oil.

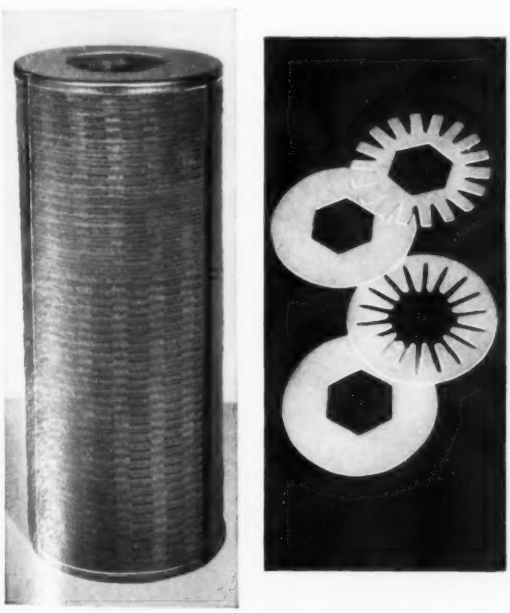
2. Baffle Gravity Settlers.
(For continuous, intermittent or batch purification.)

A faster but generally less effective gravity settling arrangement makes use of a baffle or tray arrangement to direct flow of oil in shallow layers. Such a system is generally used where contamination is heavy and where supplementary filtering equipment can be used. Often this baffle type gravity settler is used in a compact unit as the initial purification stage to remove the bulk of insoluble contaminants. The oil entering at the bottom passes over a number of staggered trays at various levels as it works to the top of the unit where it overflows to a polishing unit of filters or an arrangement of plate and frame presses. An automatic water ejector is common to this type of unit which in some operations is suitable for full flow continuous operation.



Courtesy of Wm. W. Nugent & Co., Inc.

Figure 7 — Gravity filter with automatic dirty filter alarm, automatic water separator and ventilator for continuous operation.



Courtesy of The Briggs Filtration Co.

Figure 6 — Extended area type cellulose disc packed filter cartridge. Designed for high flow rates and large dirt holding capacity the discs are packed in the cartridge with the filter discs separating the oil inlet and oil outlet discs in the order as illustrated.

3. Gravity Troughs.
(Similar to [2] where rapid reconditioning of badly contaminated oil is necessary.)

Plain open troughs can be used but the degree of purification is entirely dependent on the volume capacity of the trough and the rate of flow-through. Baffles are usually employed to permit ejection of oil and water separately.

Centrifugal Treatment

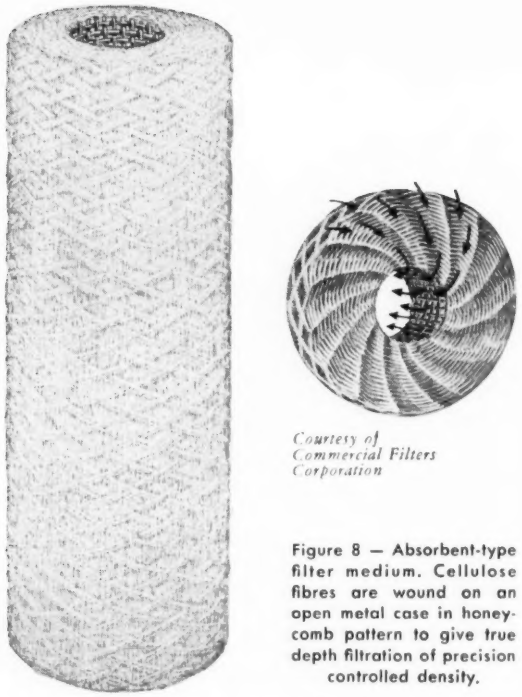
Centrifugal force is that force which tends to impel matter outward from a center of rotation. The amount of force is proportional to the distance of the object from the center of rotation and to the square of the speed of rotation.

$CF = 1.42 \times 10^{-5} DxN^2$ conveniently expressed as a multiple of the gravitational constant

CF = force
D = diameter in inches
N = rpm

The centrifuge effectually frees an oil of suspended insoluble oxidized material, foreign mineral matter, dirt, and water. It will not separate liquids which have the same specific gravities. As with settling and decantation, separation of oil contaminants is made according to gravity, accelerated by centrifugal force and is effective with any oil containing impurities heavier than the oil.

The term "capacity" as applied to a centrifuge



Courtesy of Commercial Filters Corporation

Figure 8 — Absorbent-type filter medium. Cellulose fibres are wound on an open metal case in honeycomb pattern to give true depth filtration of precision controlled density.

often is used loosely. A centrifuge may be said to have two capacities.

1. Through-put capacity, which is the total quantity of oil that can be put through the machine regardless of the degree of purification effected and without overflowing.

2. Effective capacity, which is the quantity of oil that can be put through the machine with the desired degree of purification.

Effective capacity depends upon used oil viscosity, temperature, degree of purification desired and persistency of emulsion if water is present.

An oil purification centrifuge should always be set to operate by the two-liquid discharge method. This does not necessarily mean that water should be added at the centrifuge, but the discharge opening should be provided to emit any water which may be in the oiling system.

Centrifuging is often referred to as "wet" or "dry" according to whether or not water is intentionally added to the oil at the centrifuge. Sometimes wet centrifuging is not advisable but when it will work, cleaner oil will result from the controlled addition of water to the oil at the centrifuge. Centrifuging "wet" has the following advantages:

1. The washing effect of water aids in the removal of oil insoluble impurities.
2. The water carries away the lighter weight impurities which have a gravity approximately that of water, permitting longer runs between cleanings of the centrifuge.
3. Some organic acids which may form from oxidation in lubricating oil are more soluble in water than in petroleum oil and are thus removed, reducing rate of oxidation.

The objections to "wet" centrifuging include:

1. Water-washing may remove inhibitors from some inhibited oils; for this reason it is not normally recommended for additive oils.
2. If periodic cleaning of the centrifuge is neglected, the water discharge outlet may plug causing the centrifuge to fill with water which will pass to the system through the clean oil discharge.
3. If the oil becomes dirty, emulsions may occur, aggravated by addition of water in such cases, and resulting in less purification.

In a centrifuge bowl during operation, a layer of water is formed surrounding a layer of oil, since the water is heavier than the oil. The circular metal ring* at the top of the bowl prevents that portion of water below the inner diameter from overflowing. The wider this ring or water dam, the thicker will be the layer of water in the centrifuge bowl. Since the depth of water under the ring dam balances a combined depth of oil and water in the bowl, the dividing line between the oil and water is not directly beneath the inside edge of the water dam but is located well out in the bowl.

A loss of the water layer in the bowl from leakage past a seal or from evaporation will permit the oil to discharge from the water outlet.

*The proper size of ring must be used according to the gravity of oil being used.

Courtesy of Alsop Engineering Corporation

Figure 9 — Cut-away view of disc packed absorbent cartridge element. Lubricant fills the entire filter cylinder, passes through the disc sections from above and below, then through the spacer plates to the common center outlet.

In marine service and steel mill operations, the centrifuge is usually installed directly below the gravity settling tank from which it receives its oil supply. The centrifugal purifier is widely used in such service. The purified oil is led back to the sump tank or polishing filters or directly to the bearings, according to the design of the system.

The best results will be obtained by heating the oil to around 160°F. or slightly higher, depending on the viscosity, before passing it through the centrifuge. Heaters must always be handled very carefully to prevent local overheating of the oil.

Filters

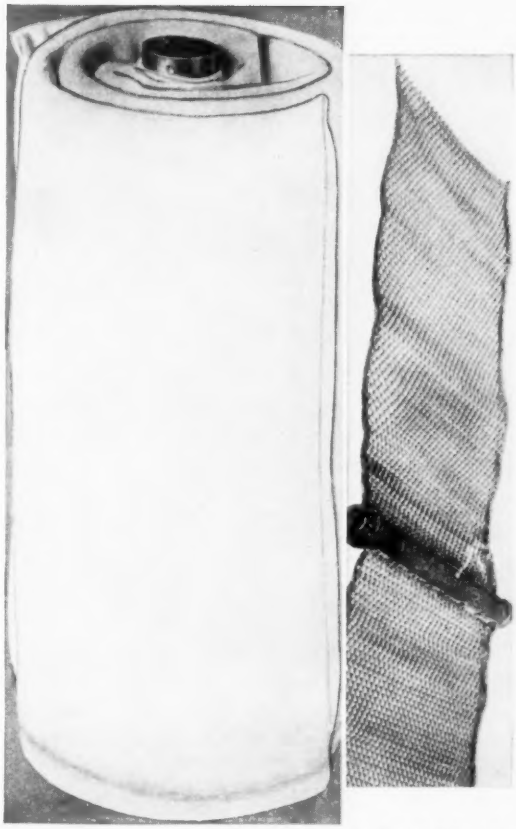
A filter is a mechanical device which acts as a barrier in the path of the oil and serves to remove the non-oil components. Filter media may be solids such as porous metal, metal screens, or composition materials; semi-solids such as paper or cloth; or loose materials in powder form such as Fuller's earth, bone-black, etc.

A wide variety of filters are available today and the proper selection depends upon full knowledge of the conditions under which such a unit will be used and the types of contaminants to be encountered. For example, the most efficient filter for a given job may have an excessively high plugging rate and would not be practical.

Filters (with exception of flat strainers) are generally composed of suitable housings and filtering elements or cells. The various types, some of which may be incorporated into a single compact unit, can be divided into four main categories.

1. *Mechanical Filters.*
   a. Metal screens.
   b. Edge-type filters. Cartridges of steel wool, copper ribbons, or closely packed discs of thin metal, or paper.
   c. Web-type filters.
   d. Extended area surface-type filters.
   e. Bag-type filters.

Filters in groups (a) and (b) are designed for use in pressure circulating systems and will remove coarse contaminants such as metal chips, grit, scale, etc. Insoluble oxidized material is generally not removed unless the size of the particles is sufficiently large to be caught by the filter element openings. Nor can soluble oxidized material, finely divided carbon particles, water, dust and the finer oxidized materials be removed by such filters. Some edge type filters are made by packing cartridges with layers of impregnated cellulose discs with alternate layers of cellulose spacers or layers of metal discs with suitable spacers; the openings between the discs determining the flow rate, contaminant capacity and efficiency. Others are made by packing cartridges with metal wool or by helically winding impregnated cellulose or metal ribbon to form self-contained cylinders. Here again, the space between the metal wool strands or ribbon determines the flow rate, contaminant capacity and filter efficiency.

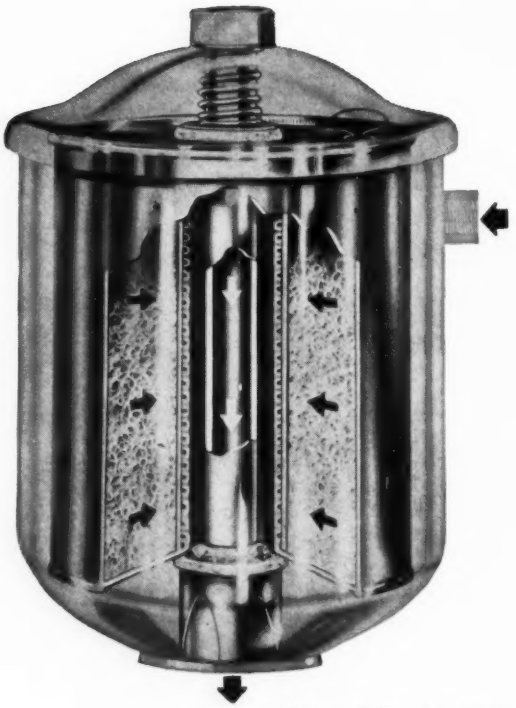


Courtesy of General Filters Inc.

Figure 10 — Cleanable all-wool felt filter cartridge over wire screen support for pressure circulating systems.

(c) Web-type belt filters for filtering by gravity are used in open operation for continuous removal of large amounts of bulk contaminants where heavy contamination is a major problem. This rotating type of self-cleaning filter of reinforced close woven fabric is especially useful in the machine-tool field. The rate of oil flow through such a filter will depend on the oil viscosity, web thickness and degree of contamination.

(d) The extended area filter is most generally used with internal combustion engines where only limited space is available. This type makes use of pleat-folded impregnated paper in replaceable cartridges to give the largest possible filter surface area per unit volume. These filters do not channel as do most waste or bulk-type filters. In automotive truck and tractor systems where used extensively, they are either by-pass, full-flow, or shunt con-



Courtesy of Fram Corporation

Figure 11 — Cut-away view of cellulose pack filter with replaceable cartridge.

nected and serve this type system very efficiently. The trend is toward the use of full-flow connection with suitable safety valves to guarantee oil feed to critical parts. For example, some automotive systems with hydraulic valve lifters employ a combination full-flow by-pass system. The filter system is arranged to give full-flow filtered oil to the hydraulic valve lifters and by-pass arrangement for the rest of the lubricating system. Suitable safety valve arrangements insure oil flow at all times. The adoption of a system of this type serves to illustrate the necessity of having clean, well-filtered oil supplied to the valve lifter continuously to prevent sticking and wear and resultant loss of power, noisy operation and high maintenance costs. Usually such filters are equipped with inserts that can be replaced at intervals as they become "loaded."

(e) Bag filters of re-enforced cloth construction are used a great deal for oil conditioning and may be employed alone or in conjunction with other systems. Some systems employ a compact unit combining gravity settlers in conjunction with a series of replaceable bags. The gravity dry process permits removal of water in the precipitation chamber and sludge and solids removal in the filter bag compartment. In the precipitation compartment oil passes upwards through a series of screen trays for removal of free moisture which is automatically ejected from the bottom of this compartment. The oil overflows from the top trays into the bag filter compartment. In some systems the oil is forced into the bags from the outside by gravity and clean oil discharges from the spouts on top of the submerged filter bags. When bags clog, oil level rises indicating need for cleaning. Manufacturers prescribe materials for cleaning bags which will effectively remove contaminants without excessively weakening the bag material. Most systems of this type are designed to permit removal of individual bags for cleaning while the system is in operation. Bag filters can be used efficiently for either continuous, by-pass or batch operation.

For systems where relatively higher oil viscosities prevail, pressures of 20 to 40 p.s.i. are used instead of gravity. When the pressure drop across the filter exceeds a prescribed value, bags are to be cleaned. Metal gauze or cloth may be employed for such systems. Metal gauze may be required when systems are equipped with automatic or manual cleaning devices. Some systems employ a series of bag filters in parallel, with bags interchangeable. Removal of one set of bags is permitted while oil continues to flow through others. Use of such equipment in excessively dirty systems may require very frequent cleanings, the life of the bags being contingent upon the frequency of cleanings. Bags are fabricated usually of cotton-wool materials unless otherwise specified; synthetic fabrics such as dynel, dacron and nylon have been used successfully under some conditions to give longer bag life.

2. Magnetic Filters.

Such filters are designed for the removal of magnetic metal particles originating from wear. Their principal application is in the ferrous metals working industry. Most magnetic filters are permanent magnets, the efficiency being dependent upon the viscosity and rate of flow of the oil as well as the size of the particles to be removed. They require a minimum of maintenance and are used in continuous operation for individual units where the oil contaminant load is so great that the use of cartridge type filters alone is uneconomical.

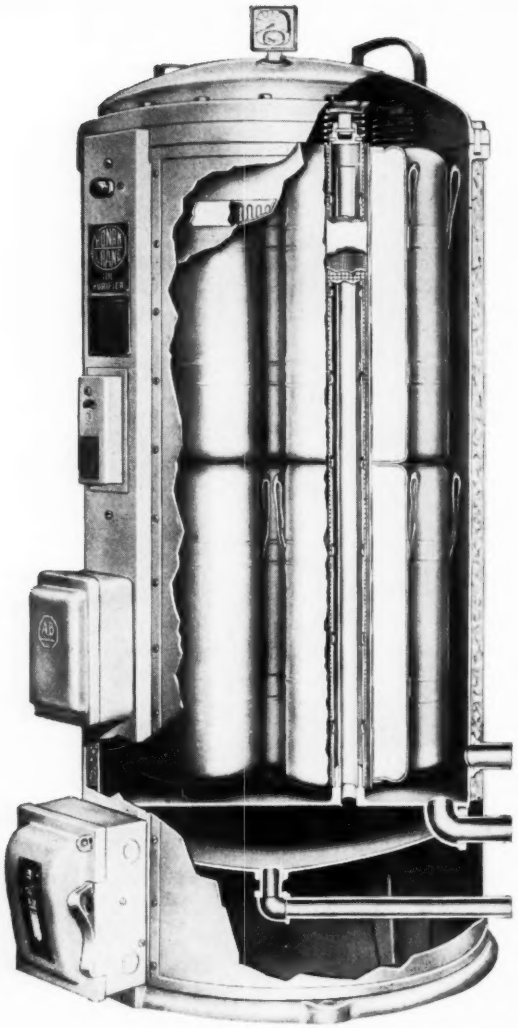
3. Absorbent Filters.

Absorbent filters, which may be of bulk or cartridge-type, employ such materials as cotton waste, wood pulp or bark, wound yarn, nylon, felt, flannel, wool, hair, paper, mineral wool, quartz, diatomaceous earth, asbestos, etc. Absorbent filters not only remove coarse contaminants but go a step further by removing more of the finely divided insoluble oxidized materials, some moisture and some acids formed through oil oxidation. Filtration is accomplished by adhesion of contaminants to the surfaces of the filtering material and absorption by the components of the filter due to porosity. Efficiency will

COMPARISON OF OIL PURIFICATION AND FILTRATION METHODS IN SERVICE

	GRAVITY PURIFICATION			*FILTRATION*				*Dehumidifiers Vaporizers and Heaters*
	Gravity Settling	*Centrifuging*		*Mechanical Filters*		*Absorption Filters*	*Adsorption Filters*	
		Dry	*Wet*	*Bag and Pleated Cellulose Filters*	*Other Mechanical Types*			
FILTERING MEDIA	....	....	....	Inactive	Inactive	Inactive	Active	...
APPLICATION TO SYSTEMS								
Full Flow	No	No	No	Some	Yes	Not Generally	Not Generally	In some systems
By-Pass	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shunt	No	...	...	Some	Yes	Yes	Yes	...
Batch	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CONTAMINANTS REMOVED								
Insoluble Solids								
Large particle size	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Small particle size	No	Some[1]	Most	Yes	No	Yes	Yes	No
Insoluble Oxidation Products								
Agglomerated	Some	Most	Yes	Yes	Some[2]	Yes	Yes	No
Dispersed	No	Some	Some	Some	No	Some	Yes	No
Soluble Oxidation Products	No	No	Some	Some	No	Little	Most[3]	No
Water	Yes	Yes	Yes	Some	No	Some	Some	Yes
Water Soluble Materials	Yes	Yes	Yes	Some	No	Some	Some	No
Dissolved Gases	No	No	No	No	No	No	No	Yes
Fuel Diluent-Light	No	No	No	No	No	No	No	Yes
Heavy	No	No	No	No	No	No	No	No
Oil Additive Removal	No	No	Some[4]	No	No	No	Some[5]	No

[1] Providing particles are heavier than oil.
[2] Depending upon size of agglomerates.
[3] Depending on type of media.
[4] Those which are water sensitive.
[5] Depending upon type of additive.



Courtesy of Honan Crane Corporation

Figure 12 — Multi-cartridge refill-type depth filter for continuous operation in circulating oil systems. Employs either adsorbent or absorbent filter media.

normally improve with use as a filter bed builds up. Excessive water contamination may materially reduce the efficiency of such units, however, and preliminary heating, vacuum moisture removal or gravity settling methods are often employed with such filters when excessive water contamination is encountered.

Depth-type filters require the oil to flow through a depth of filter medium and may be either of the replaceable cartridge or bulk type. The element itself will usually be in the form of a metal cylinder with an inner clean oil outlet tube. Oil will flow from the outside through the sock filter, perforated screen and filter depth to the outlet tube on the inside. Changes normally are controlled by noting pressure drop; excessive pressure drop indicating need for change. These can be of constant or graded density. With the latter, the density can be controlled radially and concentrically. Smaller particles therefore can penetrate to greater depths in the filter and prevent early rapid sealing of surface with resulting decreases in oil through-put. On by-pass or shunt connected systems, oil appearance can be noted or oil analysis may be required to indicate when filters have become plugged. With detergent oils, an examination of the filter itself is required to determine whether it has reached its useful life. Channelling is often encountered with some bulk type media and when such occurs, filtering efficiency is greatly diminished.

4. Adsorbent Filters.

Adsorbent-type filters contain fuller's earth, bone black, charcoal or some active type of alumina or clay. In addition to removing coarse and fine contaminants, filters of this type also remove soluble oxidized material. Since water tends to make this medium ineffective if there is much present in the oil, many adsorbent filters also contain absorbent media or other means for removing the water. With some clay type filters, the clay may mud pack or channel and prevent further action on the oil.

In filters of this type, oil contaminants not only adhere to the surfaces of the filtering material but also actually penetrate. This may be a disadvantage when dealing with an oil containing a chemical additive, for the filtering material may remove the polar chemical detergent, corrosive or oxidation inhibiting components. Obviously, extreme care should be observed in applying adsorbent type filters to a lubricating system. With straight mineral oils, however, they have proven very effective in increasing useful oil life.

Adsorbent type filters are available alone or in combination with absorbent and mechanical filters in a single compact unit. The units may be replaceable cartridge or bulk type. Filtering material can be procured for the bulk type so that the user can fabricate his own refills. Knowledge of how to pack these filters, however, is of utmost importance to insure against channelling in use. For high flow rates, multiple cartridge units are advisable.

The objective is to remove the harmful oil contaminants as rapidly as possible through a device as small as possible without removing oil additives and at the same time permit adequate and uninterrupted flow of lubricant to the system.

FILTER AND PURIFIER ARRANGEMENTS IN PRESSURE CIRCULATING SYSTEMS

There are four commonly used methods of installation.

The *By-Pass method*, perhaps the most common, operates on only a portion of the oil in the system and takes its supply off the main lubricant line usually between the discharge pump and the lubricant cooler. The amount by-passed is generally only approximately 10% of the quantity of oil circulated by the oil pump and this is returned generally to the sump. By this arrangement, the lubricated area is never supplied with 100% purified oil.

The *Independent* System makes use of a separate auxiliary pump completely separate from the lubricating system. Here a portion of the system oil is pumped through the filter or purifier and then returned directly to the sump or crankcase.

The *Shunt* connection as used with cartridge filters allows the flow of oil from the lubricating oil pump to pass through the oil filter. These shunt type filters are equipped with relief valves. The entire flow of oil at first goes through the cartridges. As the cartridges become saturated with contaminants, the flow of oil is divided. Part of the oil then goes through the cartridge and the balance goes through the clean oil compartment where it mixes with the clean oil which has passed through the cartridge.

The *Full-flow* connection as used with filters is identical with the shunt hook-up. Basically, the difference in the two methods is that the 100% flow filter must contain sufficient cartridges for a given unit to permit all of the oil entering the filter to pass through the cartridges without by-passing through the relief valves under normal operating conditions.

In selecting a filter for a circulating oil system, the question of compatibility of the oil with the filter media should be considered. Some chemical additives used in some present-day oils may not be compatible with a particular filter media under the conditions of use and may lead to unsatisfactory filter performance and/or short filter life.

RANGE OF USAGE

The following covers a few of the fields where oil conditioning equipment is a must in maintaining oil quality level in service.

Internal Combustion Engines

The oil filter or purifier is second only to the air cleaner in importance as auxiliary equipment for the internal combustion engine. Oil cleanliness has a directly measurable correlation with engine

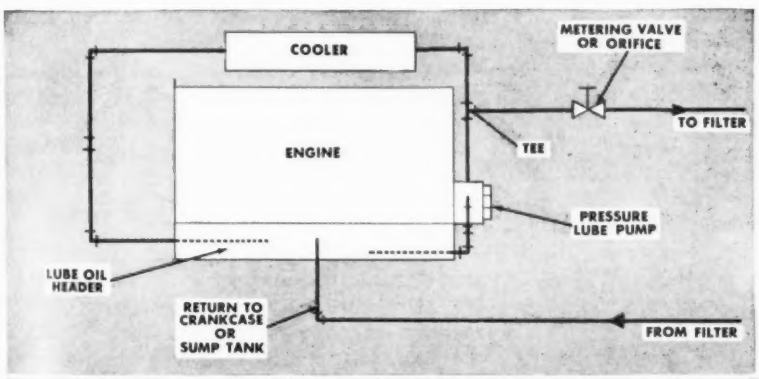
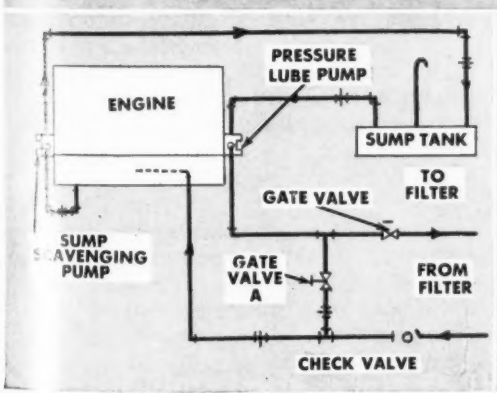
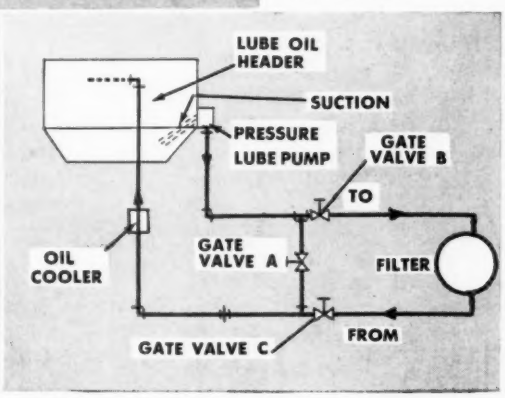


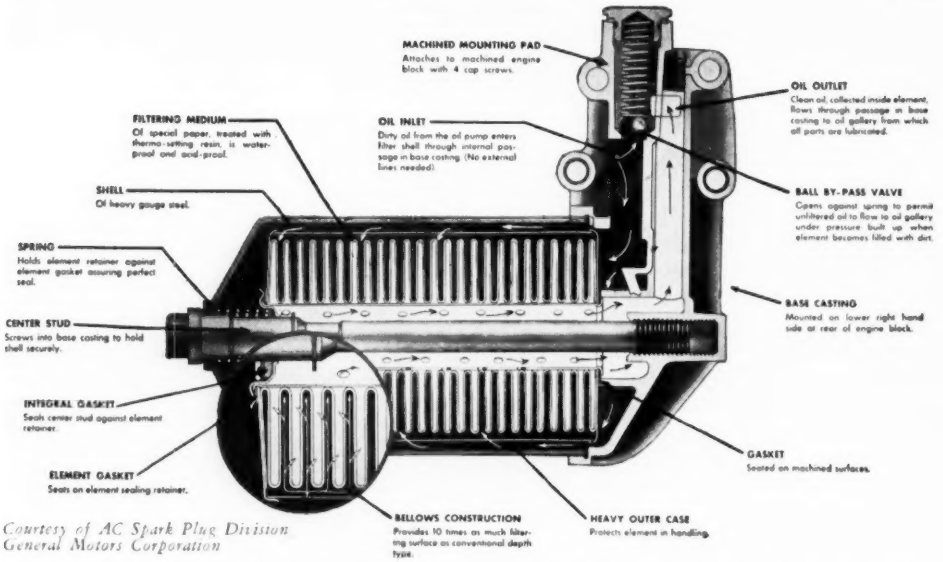
Figure 13 — Top view — Typical by-pass installation accomplished by installing a tee in the line from the pressure lubricating oil pump to the lubricating oil cooler, allowing oil to by-pass to the filter through a metering valve or orifice.

Courtesy of The Briggs Filtration Co.





Bottom left — Typical shunt installation in the pressure line.
Bottom right — Typical 100% flow installation in the pressure line (Wet Sump Engine).


MACHINED MOUNTING PAD
Attaches to machined engine block with 4 cap screws.
OIL OUTLET
Clean oil, collected inside element, flows through passage in base casting to oil gallery from which all parts are lubricated.
FILTERING MEDIUM
Of special paper, treated with thermo-setting resin, is water-proof and acid-proof.
OIL INLET
Dirty oil from the oil pump enters filter shell through internal passage in base casting. (No external lines needed)
SHELL
Of heavy gauge steel.
BALL BY-PASS VALVE
Opens against spring to permit unfiltered oil to flow to oil gallery under pressure built up when element becomes filled with dirt.
SPRING
Holds element retainer against element gasket assuring perfect seal.
BASE CASTING
Mounted on lower right hand side or rear of engine block.
CENTER STUD
Screws into base casting to hold shell securely.
INTEGRAL GASKET
Seals center stud against element retainer.
GASKET
Seated on machined surfaces.
ELEMENT GASKET
Seats on element sealing retainer.
BELLOWS CONSTRUCTION
Provides 10 times as much filtering surface as conventional depth type.
HEAVY OUTER CASE
Protects element in handling.

Courtesy of AC Spark Plug Division General Motors Corporation

Figure 14 — Typical extended area type automotive cartridge filter for full-flow connection. By-pass safety valve is incorporated to permit flow of oil should filter become plugged on extended use. The resin impregnated filter paper element is formed into bellows proportioned to give each convolution ample oil passage and spaced to give optimum dirt and sludge capacity.

wear, operating and maintenance costs, out-of-operation time, length of time between overhauls, etc. Equipment manufacturers and users feel that efficient oil conditioning equipment, especially with full-flow continuous operation will result in 50% reduction in wear and 50-60% reduction in overall costs. This is understandable when it is considered that practically all of the contaminants described previously can be found in used internal combustion engine oils at one time or another. Aside from engine wear, such contaminants contribute in no small way to bearing corrosion problems, oil line plugging with subsequent oil starvation, stuck valves and hydraulic valve lifters, ring sticking, oil ring plugging, etc.

Of the four types of internal combustion engines in common use today, gasoline, gas, dual-fuel and Diesel, the latter is by far the dirtiest and gas is the cleanest. Diesel operation therefore presents the greatest problem in oil maintenance.

The seriousness of contaminated oil in modern high speed, high compression engines of today and the necessity of preventing contaminant build-up in critical areas has brought about the widespread use of heavy-duty high detergent motor oils. These oils are essential with modern complex design engines to preserve the high power, high fuel economy, trouble-free smooth operation available. They do not, however, eliminate the need for filters.

Although a wide variety of filters and oil purifiers are used in stationary service, the space limitations of on-the-road units generally necessitate the use of relatively small filter cartridges. This explains the wide acceptability of the extended area type. There is a rapid trend towards the use of the full-flow design. Special design units are available to provide full-flow filtered oils to critical areas with shunt or by-pass filtered oils to less critical areas. The ultimate is a unit designed to give high flow rates at very low pressure drops; to have unlimited contaminant capacity and give efficient purification.

Automotive Service

Space limitations necessitate the use of relatively small replaceable cartridge or replaceable unit filters, and the widespread use of heavy-duty detergent additive oils generally restricts the filter media to the absorbent-mechanical types. Wide usage is made of folded, impregnated paper, replaceable cartridges of the extended area type, waste packed cartridges of the depth type and paper or thin metal disc cartridges of the edge type. These are in addition to the mechanical filter screens at oil pump intake which is standard equipment.

Most cars today come fully equipped with such auxiliary filters. Although the trend is towards full-flow oil filtration, the majority are installed in by-pass or shunt arrangement. Some cars are equipped with a full-flow filter in the oil supply line to the hydraulic valve lifters where utmost oil cleanliness is imperative. The remainder of the system works on by-pass filtered oil. Filters in by-pass or shunt arrangement effectively filter the oil that passes through them. However, such arrangements do not provide the lubricating systems

with fully filtered oil since such oil is returned from the filter to the crankcase. The lubricating system is thus always supplied with a mixture of filtered and unfiltered oil. Full flow filters are equipped with relief by-pass valves to insure of continued oil supply in case of filter plugging.

Although maintenance procedures vary greatly, the generally accepted practice is to replace filters or filter cartridges every 6000-7000 miles with 1000-mile oil changes, except in cars equipped with hydraulic valve lifters where the prescribed practice is for 5000-mile filter changes with 1000-mile oil changes.

Typical oil analysis after normal usage in automotive road service with and without the use of a pleated paper extended area type replaceable cartridge filter in by-pass connections.

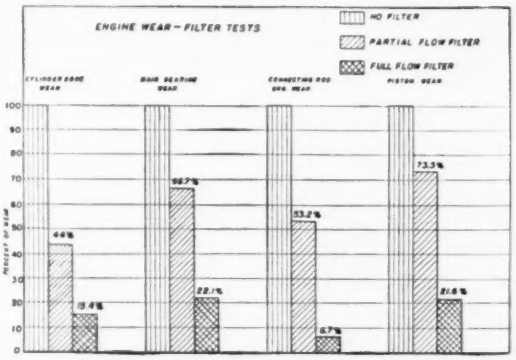
	NO FILTER		WITH FILTER	
	New	*Used*	*New*	*Used*
Solids, plus insoluble resins	None	1.5	None	0.1
Solids, %	None	0.3	None	0.02

TYPICAL USED AUTOMOTIVE OIL ANALYSES

	New Oil	Following Low Temperature Operation As Drained	Following High Temperature Operation As Drained
Acid No.	0.06	4.7	5.2
Dilution, %	0.0	15.8	0.0
Oil Insolubles, %	0.0	2.07	1.16
Oil Soluble Oxidation Products	0.0	0.20	3.09
Acid No. on Oil Insolubles	..	17.2	28.8
Acid No. on Soluble Oxidation Products	..	..	63.2

Average typical analyses of several low temperature sludge deposits found in the crankcases of automotive engines.

	AS RECEIVED	OIL FREE
Oil, %	83.1	...
Water, %	6.2	36.7
Gasoline Diluent, %	4.7	27.8
Free Carbon (Fuel Soot), %	1.6	9.5
Oxidized Material, %	0.8	4.7
Free Mineral Matter, %	3.6	21.3
Chief Components	Lead, Iron, Aluminum	...
Minor Components	Copper, Silica	...



Courtesy of Purolator Products Incorporated

Figure 15 – Results of 5,000 miles of road testing on 25 gasoline engine powered cars. The 100% of wear indicated is considered to be the amount of wear obtained without oil filters of any type. Results represent those obtained under average of driving conditions encountered in all parts of the country using all types of fuel and all types of lubricating oil.

Diesel Motive Service

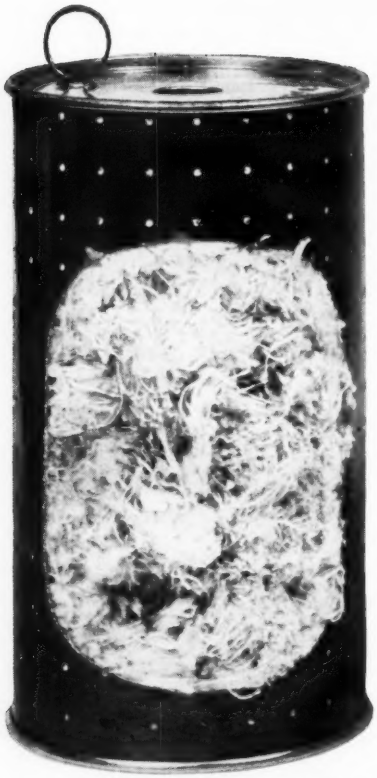
Here again, space limitations severely restrict the size and type of filter as it is used with on-the-road Diesels. The use of additive oils in this service further restricts the type of filter. Absorbent materials of waste (primarily cotton) and shredded redwood bark in replaceable cartridges (cloth socks reinforced with screen strainers) are finding widespread use in Diesel service. Extended area (pleated paper) type cartridge filters are also used to some extent in full-flow or by-pass connection. Because of the relatively large fuel, soot and dirt contamination and the widespread use of detergent oils the proper selection of an efficient filter is of great importance in Diesel maintenance.

Industrial Service

In industrial service, where space limitation is not as important a factor, a number of satisfactory oil conditioning systems can be employed. In addition to the wide variety of equipment used for individual engines for full-flow continuous or by-pass operation, portable purifiers and filters are often employed to service several engines. Diesels again present the greatest problem of oil purification.

Aircraft Service

Oil purification and maintenance in service with aircraft reciprocating engines is very desirable and necessary to reduce engine wear and increase time between presently required overhaul periods. Success has been somewhat limited, however, because of the space restrictions, high oil flow rates and high oil pressure encountered. Absorbent cartridge filters in by-pass connection show little improvement in reducing engine wear. Airlines are currently investi-



Courtesy of Purolator Products Incorporated

Figure 16 — Waste-packed filter element as employed in by-pass systems.

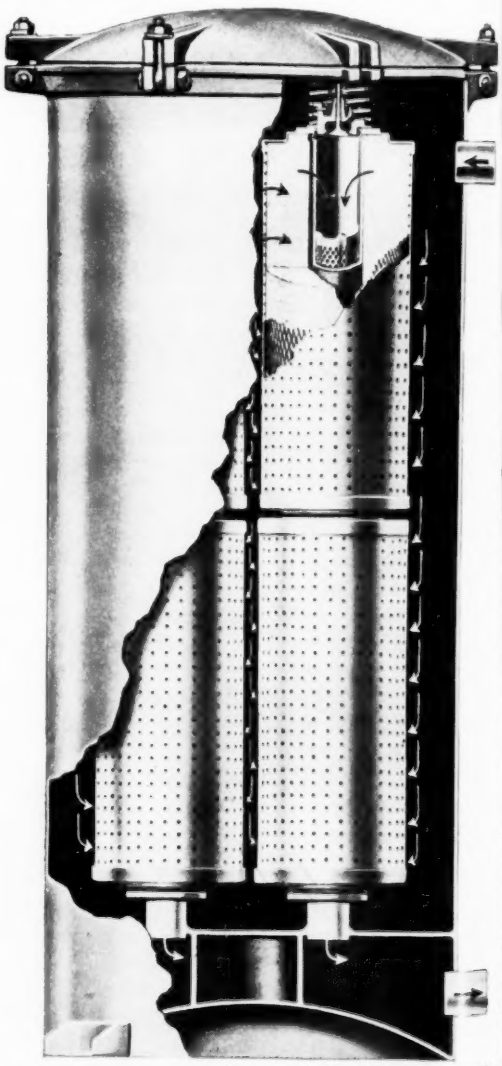
gating the possibility of using (1) specially designed extended area filters in full-flow systems or (2) specially designed centrifugal purifiers in continuous by-pass arrangement. Additive engine oils for use in aircraft reciprocating engine service also promise some relief from deposits and wear on critical parts.

Steam Turbines

Oil conditioning equipment plays a most important role in the preparation of new steam turbine lubricating systems, in the flushing of used systems and in the maintenance of lubricating oil during operation.

Water, rust, dirt and wear particles are the contaminants of principal concern in the maintenance of steam turbine lubricating systems. Present-day turbine lubricants are designed to afford top overall performance and system protection even in the presence of these contaminants. Yet, with heavy contamination, assistance is required through use of auxiliary purification equipment to extend the useful life of the oil and prevent the eventual formation of sludge and rust. Highly refined oils with good water separating characteristics, incorporating anti-foam, anti-rust and anti-oxidation additive are serving the needs of the steam turbine syste in remarkable fashion. Relatively simple mainte nance programs providing for oil conditioning equipment will preserve these oil qualities an afford dependable lubrication for extended period Use of these additive oils prohibit employment o adsorbent type filter materials, although other pur fication designs can be used with entire satisfaction

Water contamination probably is of greatest con cern. In addition to the problems of sludge forma tion and oil emulsification, excessive water wi cause depletion of the rust inhibitor and without it rusting can occur at a rapid rate. Rusting, especiall



Courtesy of The Hilliard Corporation

Figure 17 — Combination pack cartridges suitable for direct connection to circulating systems on a full-flow, shunt or by-pass installation.

in critical areas as in governors, actuators, etc., cannot be tolerated.

Entrance of water may be:

1. From steam leaks due to faulty shaft packing glands or seals.
2. Through leaks in cooling coils (salt water on marine units is even more dangerous).
3. Condensation from moisture in the air.
4. Above normal gland water temperatures.
5. Steam blow-by when glands become scaled or vacuum is lost resulting in "steaming" of the bearing.

The use of dehumidifiers on tank breathers will help to reduce moisture contamination from condensation and in addition, any of the following auxiliary oil purification equipment may be used very effectively in maintaining turbine oil quality level.

(a) Gravity Settlers—for batch treatment of oil for separation of excess water and suspended insoluble oxidized material, dirt, etc. Settling purification is normally conducted by heating oil to approximately 120-140° F. and allowing oil to stand for several days.

(b) Centrifuge treatment of oil for faster and more complete removal of contaminants as noted in (a). Centrifuges are generally connected to the sump for intermittent or continuous handling of the oil. The oil is supplied through an auxiliary pump. Wet centrifuging for removal of soluble oil oxidation products is generally only employed with straight mineral oils as such treatment with inhibited oils will cause inhibitor depletion.

(c) Widespread use is made of filters adapted to force-feed lubricating systems. Such filters are limited to mechanical or absorbent types except where straight mineral oils are employed. Compact filter units are also employed successfully working off the unit sump and generally are of the three compartment type. The first compartment is a series of baffled trays for bulk water removal. The oil overflows from this precipitation compartment to a series of gravity filter bags from where it is pumped through cellulose polishing filters where the most finely divided particles of oxidized material and moisture in suspension are removed.

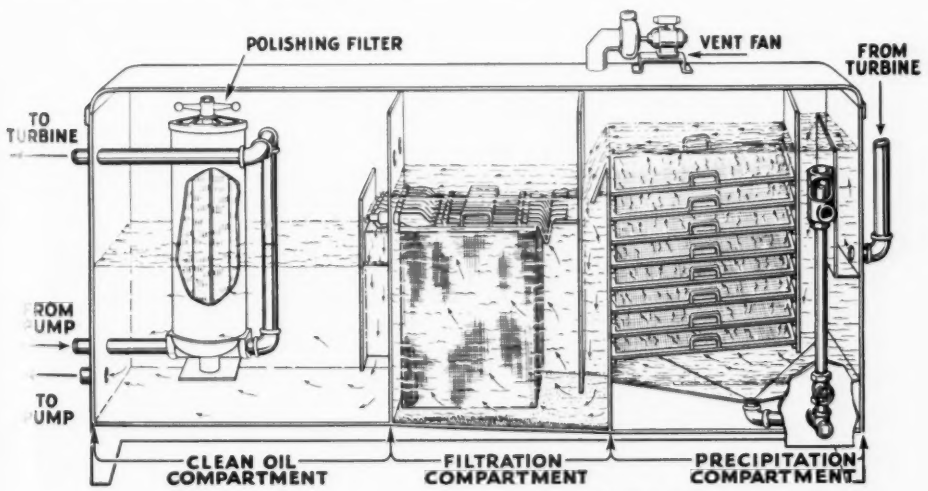
In the cleaning of steam turbine lubricating oil systems,* continuous operation of the purification auxiliary equipment is essential to eliminate the abrasive materials and trash contaminants often left after assembly of the new or repaired system and the sludge, rust, dirt, etc., loosened in used systems.

Hydraulic Oils

Oil cleanliness is of paramount importance in hydraulic systems.

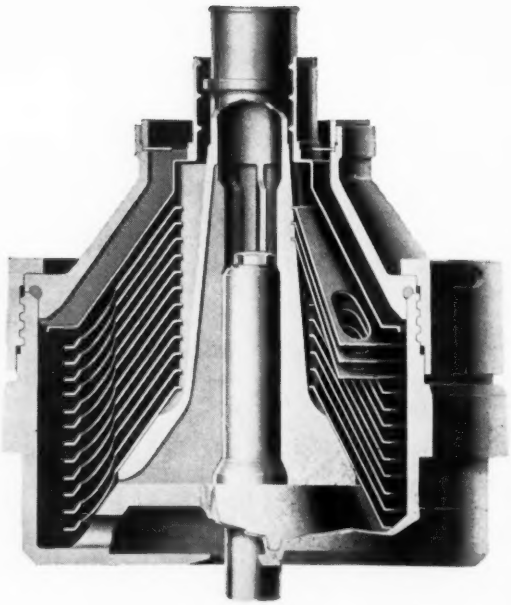
The same types of oils as used in steam turbine lubricating systems are generally employed in hydraulic service. These are highly refined, inhibited oils with good water-separating characteristics. The fact that they are of the inhibited type precludes the use of adsorbent type (active) filters, although in systems employing straight mineral oils, such active filters can be used to advantage. Other purification equipment as described under Steam Turbine Oils can be used.

*Practices for the preparation of new systems, for the cleaning of used systems and for the purification of turbine oils have been prepared by a Joint ASTM-ASME Committee on Turbine Lubrication.



Courtesy of Bowser, Incorporated

Figure 18 — Typical oil conditioning unit for steam turbine lubricating system.



Courtesy of The DeLaval Separator Co.

Figure 19 — Sectional view of a centrifugal purifier bowl used for removing water and dirt from oil. The bowl is fitted with a series of conically shaped discs which divide the oil into a large number of thin layers. Rapidity and effectiveness of purification is based on this thin strata distribution principle.

Under normal operating conditions in a closed hydraulic system using inhibited oils, the quantity of contaminants entering the lubricating system will be small. However, when one considers the possible damage to expensive precision-made valves or pumps that may result from the presence of impurities, it can be realized that the use of oil purification equipment can be real economy.

The type of purification equipment will be determined by the types and amounts of contaminant. Large systems where water contamination is relatively heavy usually employ gravity settling tanks for batch purification or centrifuges for continuous or intermittent purification during service. Others can be satisfactorily handled by use of absorbent or mechanical filters, in intermittent or continuous by-pass or full-flow arrangement for removal of dirt, dust, oxidation products, moisture, etc. Strainers are usually employed in the suction from the sump while replaceable cartridge mechanical or absorbent types are connected on the pump pressure side.

Where a number of units are operating, a portable conditioner is often employed and operated on shunt connection to the various individual unit sumps.

Steel Mills

Contamination of heavy circulating oils is one problem ever present in steel mill operation. The main contaminants are water, mill scale, and dirt. The mill scale and dirt are abrasive and serve to stabilize emulsions formed from the admixture of lubricating oil with the large quantities of water that get into the lubricating system. The job is to keep the lubricants as free of these contaminants as possible. The large quantities of oil and the high degree of contamination encountered often necessitates the use of both continuous and batch purification.

The fact that water contamination is a severe problem necessitates the use of circulating oils with good water-separating characteristics. However, inadequate purification eventually results in the formation of stable emulsions and sludge which makes subsequent purification considerably more difficult.

The elaborate oil conditioning systems employed generally consist of two or more gravity settling tanks for batch removal of bulk contaminants and finally polishing cartridge or bag filters and/or magnetic strainers for removal of small mill scale particles. Compact combination unit purifiers are popular for this polishing step and combine a water or sludge precipitation compartment and a series of cloth bag filters stretched over wire frames. Metal gauze bags are also used in this combination unit where automatic cleaning of bags by manual or automatic knife or brush scraping is desired.

Where continuous gravity settling is desired as in Cold Strip Mill operation, the system is equipped with a baffled settling tank and a storage supply tank. The baffles arranged in the oil inlet side of the settler permit slow movement of oil and more efficient separation of the water and dirt which settles to the bottom and is easily removed. The clean oil overflows the baffles to the clean oil compartment where it is drawn off continuously, fed to a centrifuge or filter, and thence to the oil supply tank. Filters especially adapted to this service for continuous operation are available which will remove foreign particles down to a few microns in size.

CONCLUSION

Once it is realized that most dependable and economic lubrication will result through the selection of the most effective lubricant and the use of proper auxiliary equipment to maintain it in clean condition, the solution to the majority of lubrication problems existing in circulating oil systems today is attained. It is hoped that the foregoing will prove helpful as a guide in the selection of such equipment.

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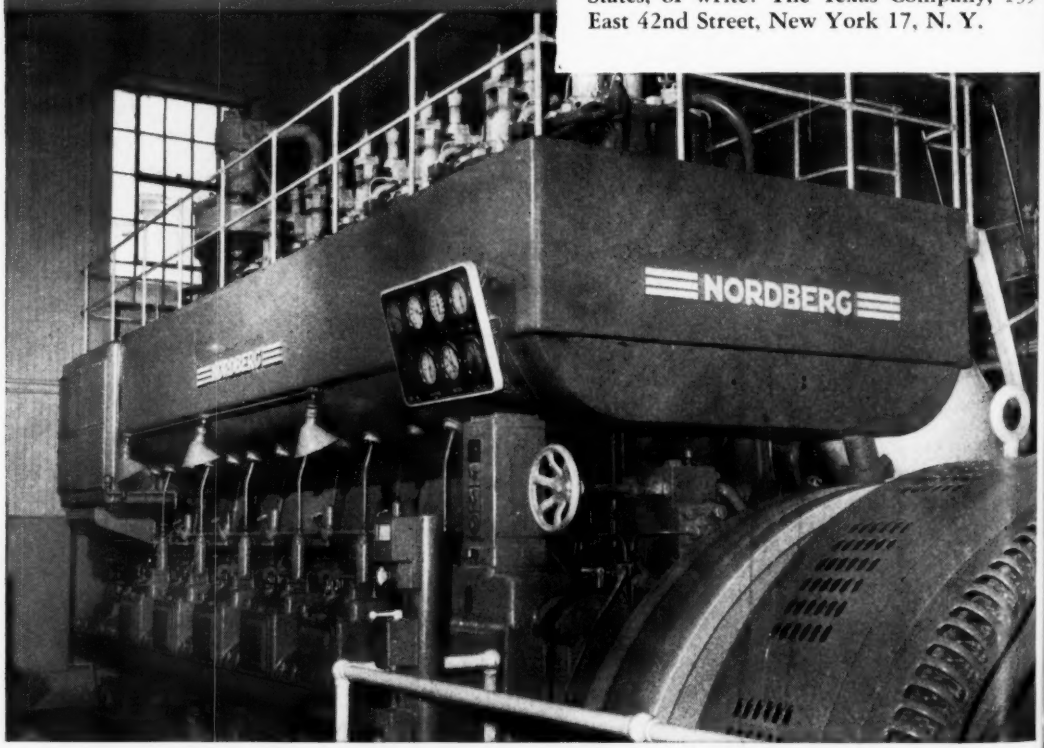

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